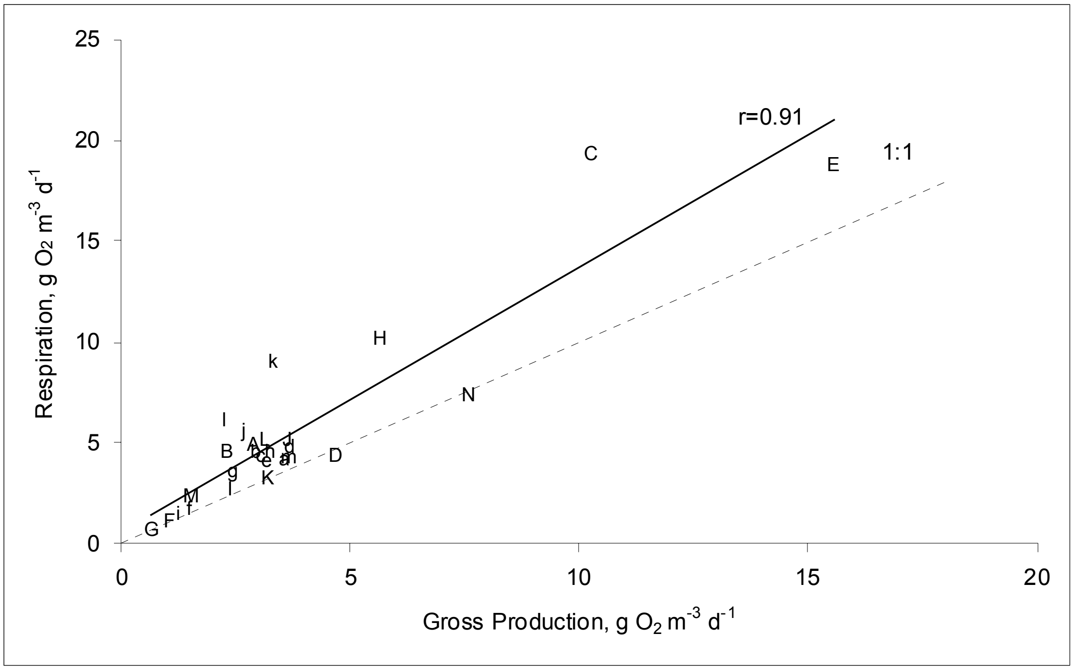

Figure 229. Mean volumetric rates of production and respiration among NERR sites. Legend used for all graphs: A-ACEBB, a – ACESP, B – APAES, b - APAEB, C – CBMJB, c - CBMPR, D – CBVGI, d - CBVTC, E – ELKAP, e - ELKSM, F – GRBGB, f - GRBSQ, G – HUDSK, g - HUDTS, H – JOB09, h – JOB10, I – NARPC, i - NARTW, J – NIWOL, j - NIWTA, K – PADBY, k - PADJL, L – RKBBR, l - RKBUH, M – WKBFR, m - WKBWB, N – WQBCB, n - WQBMP.

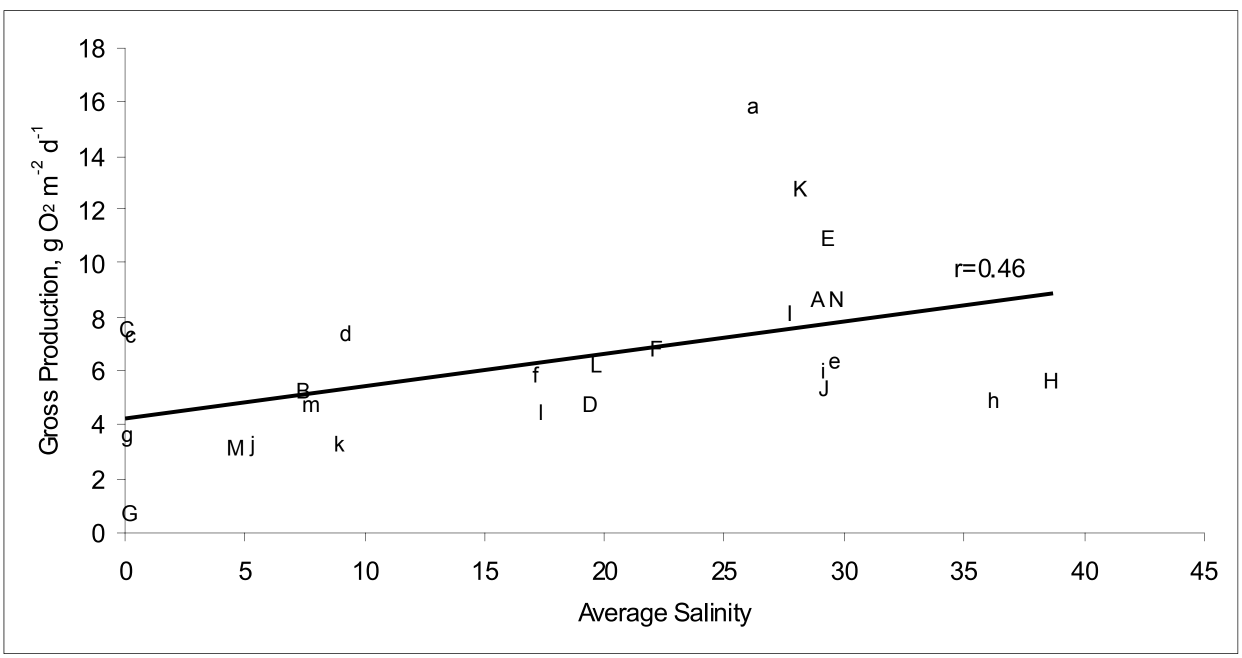

Figure 230. Gross production vs. average salinity among NERR sites.

Shallow sites (≤ 1 m) were more productive and had higher respiration rates than deep sites (> 2 m), with the exception of Padilla Bay-Bay View. At the Bay View site, the data sonde was deployed in a 4 m deep channel. The inter-tidal eelgrass beds surrounding the site are exposed at low tide; thus, the average water depth where the data sonde was located was likely deeper than the average water depth of the waterbody. Similarly, water depths were highly variable (0.7-6.5 m) between deployments among all sites. Because of this variation, volumetric metabolic rates were converted to areal metabolic rates by multiplying volumetric rates by average water depth in the area where the data sonde was located. Comparing production or respiration among the Reserves on a per m^2 basis also provides useful information, particularly at the sites with submersed macrophytes such as eelgrass or macroalgae. Thus, the deeper sites in ACE basin (St Pierre) and Padilla Bay (Bayview Channel) had the highest rates of production and respiration (Figure 231).

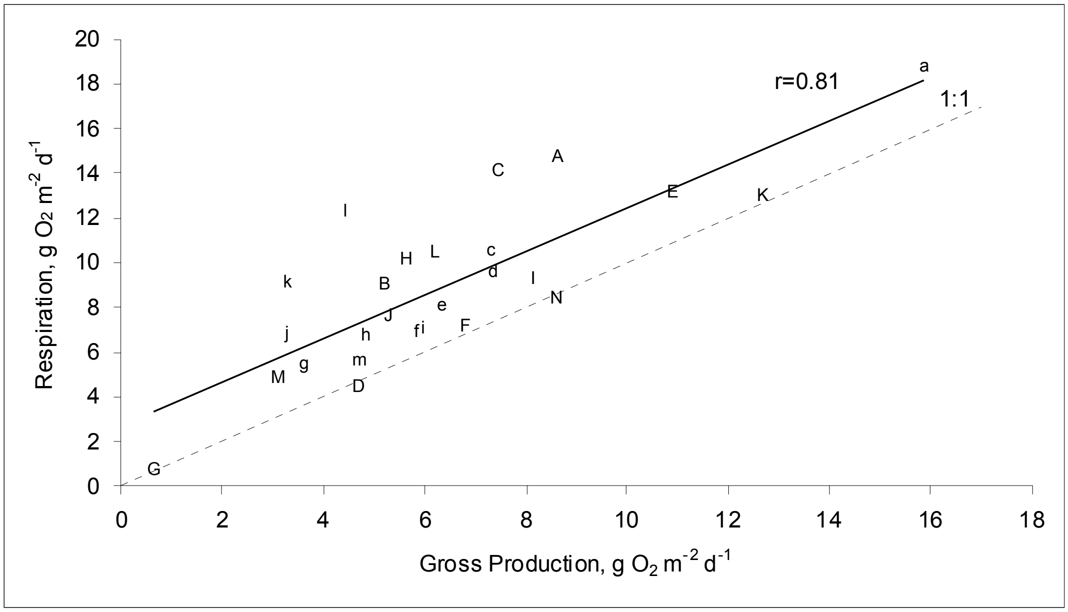

Figure 231. Areal metabolic rates among NERR sites.

Metabolic rates were not noticeably different among five geographic regions (Northeast, Mid-Atlantic, Southeast, Gulf and Caribbean, West Coast); however, there were consistent trends among different habitat types. Two sites with extensive beds of either eelgrass (Goodwin Island, Chesapeake Bay VA) or macroalgae (Central Basin, Waquoit Bay) were all autotrophic. The other eelgrass site (Bayview Channel, Padilla Bay) was balanced probably because the data sonde was deployed in a deep channel, not in the inter-tidal eelgrass bed. Four sites (Jobos Bay and Rookery Bay sites) surrounded by mangrove swamps were all strongly heterotrophic, particularly the Rookery Bay sites. Three tidal freshwater marsh creeks and six salt marsh creeks were all heterotrophic (Figure 232). Seven sites were located in open water bays or small rivers and were also heterotrophic, although the extent of this condition varied from extremely heterotrophic (i.e., Apalachicola East Bay) to moderately heterotrophic (i.e., Narragansett Bay and Great Bay-Buoy 126). Three sites located in small creeks or ponds completely surrounded by uplands were either heterotrophic (Elkhorn Slough-Azevedo Pond, Padilla Bay-Joe Leary Slough) or balanced (Hudson River-Sawkill).

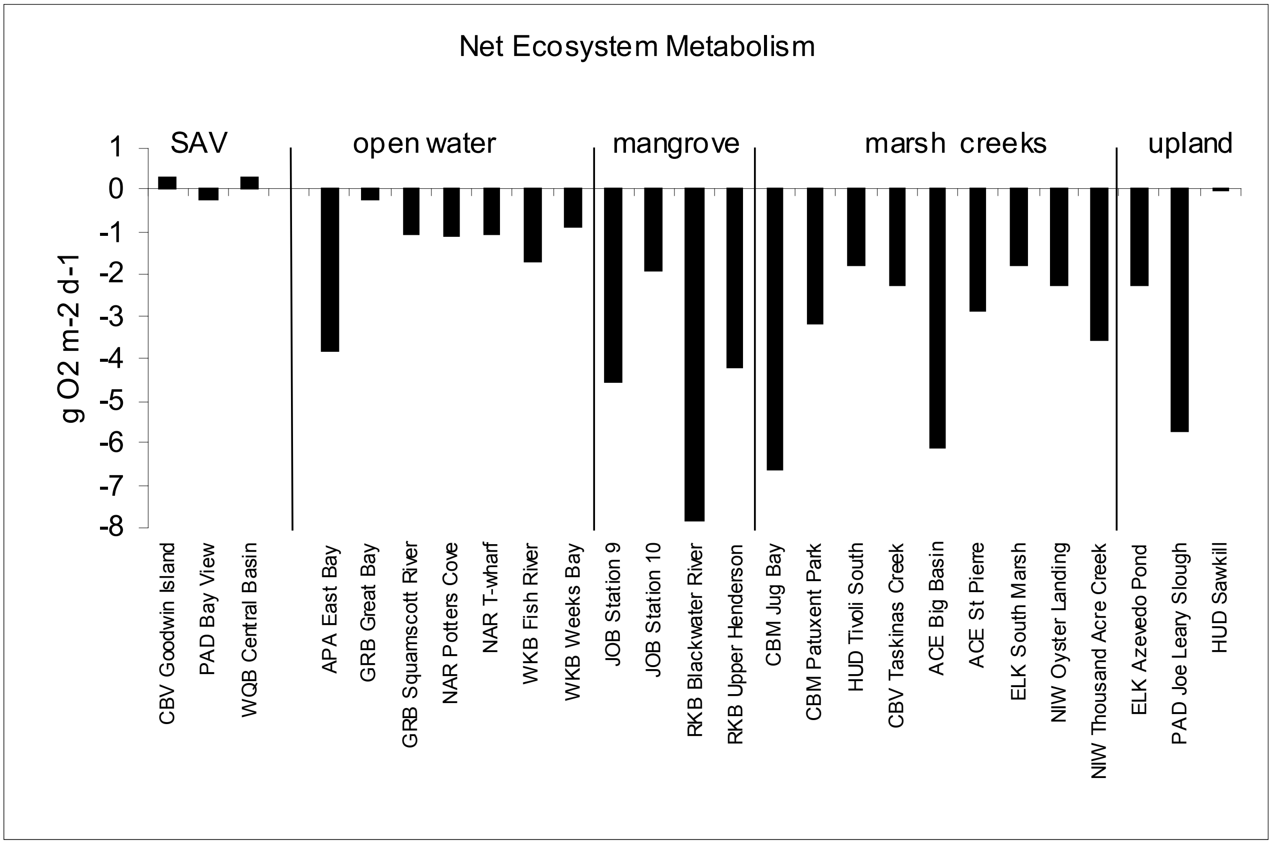

Figure 232. Relationship between net ecosystem metabolism (NEM) and habitat types.

Mean annual freshwater flow varied by over three orders of magnitude; however, the metabolic rates were not related to freshwater flow (Figure 233). Sites at reserves with intermediate flows (Chesapeake Bay-MD and ACE Basin) were generally more heterotrophic than sites with either higher or lower flows, except for Upper Henderson (Rookery Bay) and Joe Leary Slough (Padilla Bay), which had a low flow and was extremely heterotrophic.

In general, respiration was higher at the sites with intermediate freshwater fill times, which was calculated from estimates of freshwater flow and estuarine volume (Figure 234). This trend was not significant for gross production and freshwater fill time, although sites with greater freshwater fill times generally had higher gross production rates. As freshwater fill time increased, sites generally became more heterotrophic, except at Waquoit Bay-Central Basin and Padilla Bay-Bay View (Figure 235). Freshwater fill times provide a simple way to estimate residence time without including the complexities associated with estuarine circulation. Literature values of residence time were available for nine sites: Apalachicola Bay (Mortazavi et al. 2000), Chesapeake Bay Md (Jug Bay and Patuxent River Park, Hagy et al. 2000), Elkhorn Slough (South Marsh, Largier et al. 1997), Great Bay (Buoy, GBNERR homepage), Hudson (Tivoli South, Howarth et al. 1996), Narragansett Bay (Potter Cove, T-wharf, Nixon et al. 1995), and Waquoit Bay (Central Basin, Jay et al. 1997). No trend between residence time and gross production was evident; however, as residence time increased, respiration increased and sites became more heterotrophic ($p=0.06$, $r^2=0.40$, Figure 236).

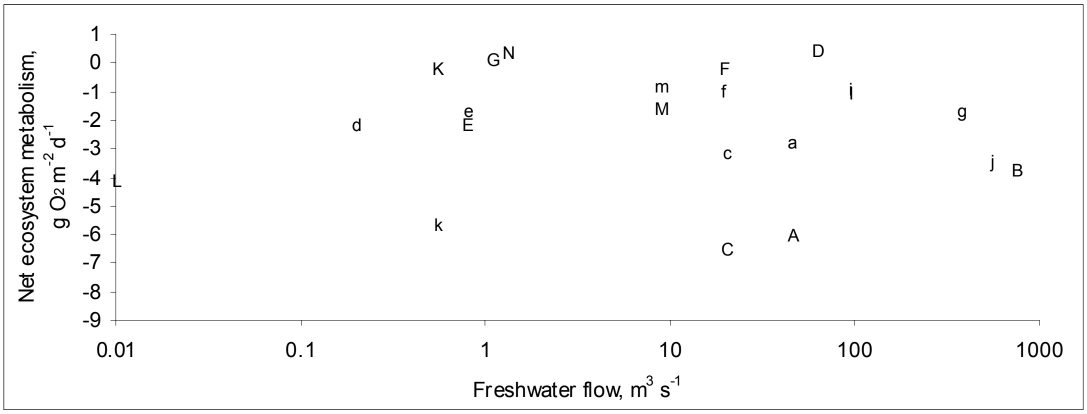

Figure 233. Net ecosystem metabolism vs. freshwater flow among NERR sites.

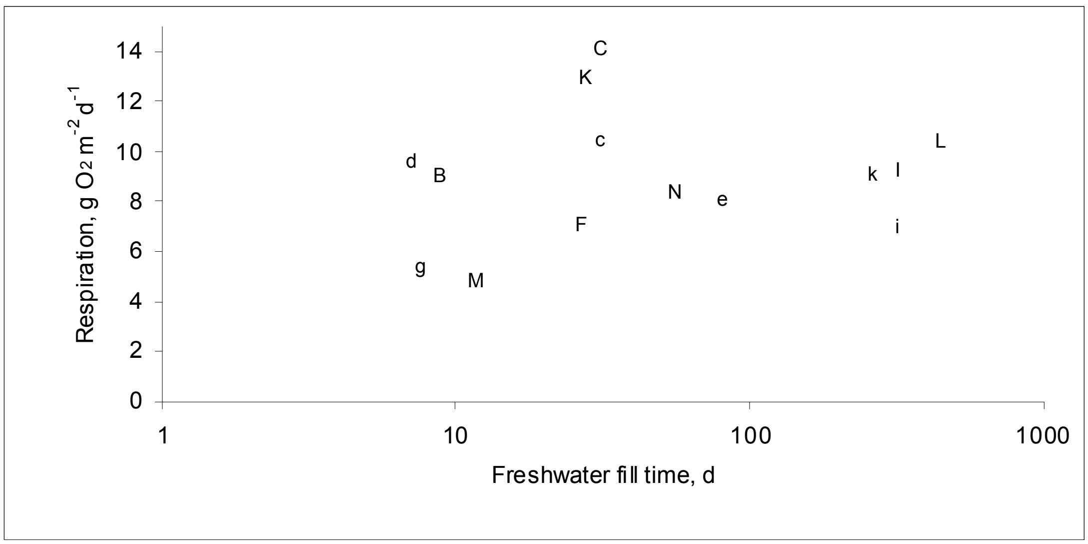

Figure 234. Respiration vs. freshwater fill time among NERR sites.

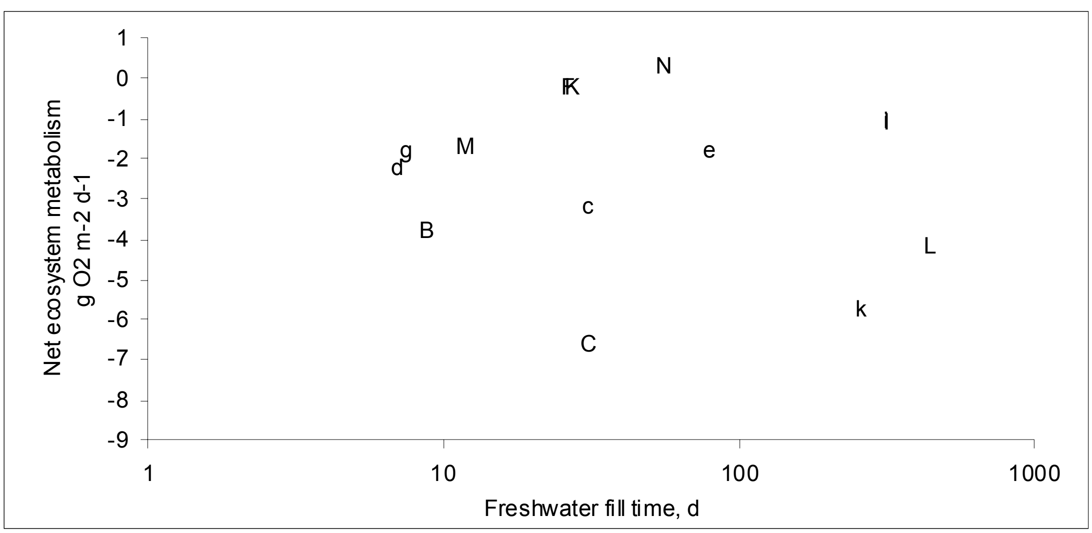

Figure 235. Net ecosystem metabolism vs. freshwater fill times among NERR sites.

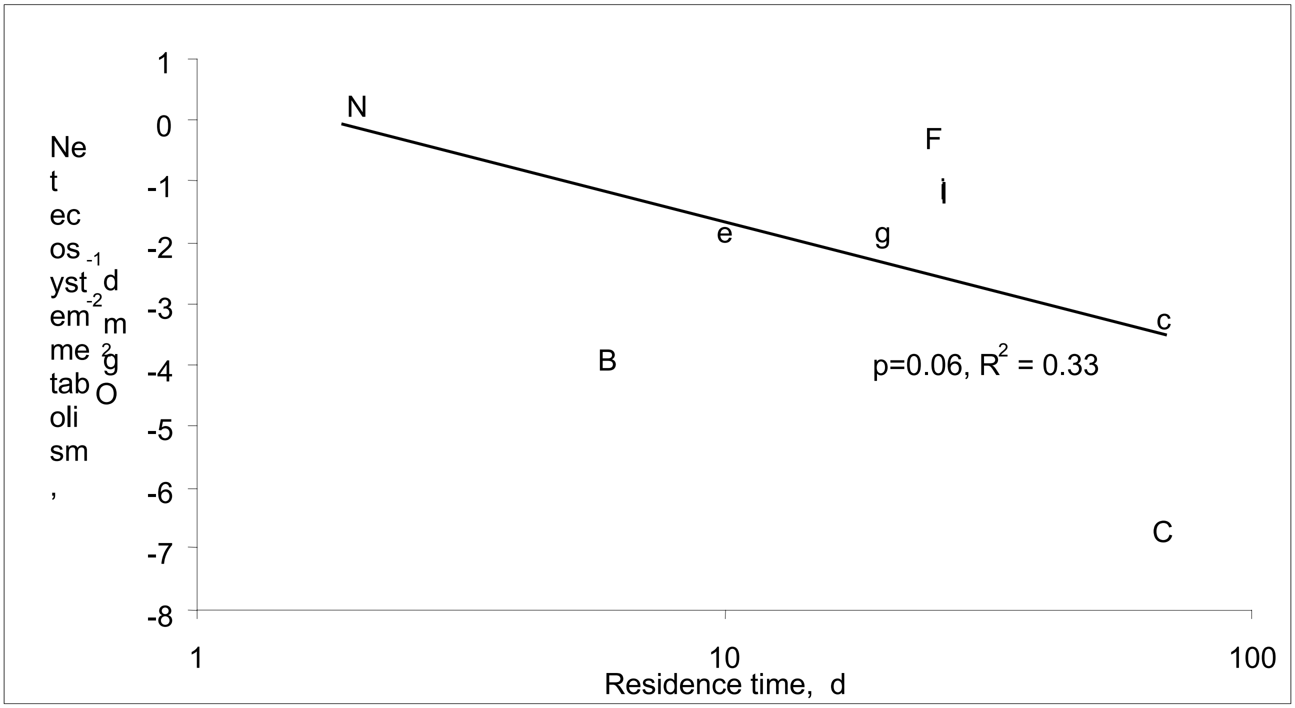

Figure 236. Net ecosystem metabolism vs. residence time among selected NERR sites.

No consistent trends were observed between metabolic measurements and either nutrient or chlorophyll *a* concentrations at the 13 sites with available nutrient data (ACE Basin-both sites, Chesapeake Bay- Goodwin Island, Elkhorn Slough-both sites, Great Bay-both sites, Hudson River-both sites, Jobos Bay-both sites, North Inlet/Winyah Bay-both sites). The range in average chlorophyll *a* concentrations was between 2-13 µg/l. Average nutrient concentrations ranged between 2-300 µM DIN and 0.1-3.5 µM DIP.

Although correlation analysis found no association between nutrient concentrations and metabolic processes, visual examination of DIN:DIP versus P:R ratios suggested increased metabolism when N and P concentrations were less than the 16:1 Redfield ratio (Figure 237). The ratio of DIN:DIP is frequently used to determine whether phytoplankton are nitrogen or phosphorus limited. Less than a ratio of 16:1 indicates nitrogen limitation. Ratios greater than 16:1 indicate phosphorus limitation. The DIN:DIP ratio by itself is not always a good predictor of trophic conditions because water column nutrient concentrations represent a balance between input and removal processes which involve both physical (advection and burial) and biological (uptake, regeneration and denitrification) processes. These data suggest that Reserve sites are unlikely to be autotrophic under nitrogen-limited conditions; however, greater heterotrophy with increasing phosphorus limitation did not necessarily occur. Phosphorus limitation of primary production, common in freshwater systems, may have occurred at the two freshwater Hudson River sites which had extremely high DIN:DIP ratios, but very different P:R ratios. All the other sites for which nutrient data were available were either mesohaline or euryhaline in character. Sites with DIN:DIP ratios between 16:1 and 20:1 were either strongly heterotrophic (e.g., both ACE Basin sites) or autotrophic (e.g., Chesapeake Bay VA-Goodwin

Islands).
Nutrient (N & P) loading rates were available from the literature or could be calculated for 9 of the sites: Apalachicola (Mortazavi et al. 2000), Chesapeake Bay MD (both sites, Boynton et al. 1995), Elkhorn Slough (both sites, Caffrey unpublished data), Narragansett Bay (both sites, Nixon et al. 1995), Weeks Bay (Fish River, Pennock 1996), and Waquoit Bay (Central Basin, D'Avanzo et al. 1996). The only association found between nutrient loading and metabolic rates was between nitrogen loading and net ecosystem metabolism (Figure 238). Sites with higher nitrogen loads were more autotrophic than sites having low nitrogen loads (Figure 238). Several researchers have reported a similar pattern (Smith and Hollibaugh 1993, 1997, D'Avanzo et al. 1996, Kemp et al. 1997). The balance between organic loading and inorganic loading seems to be particularly critical in determining whether sites are autotrophic or heterotrophic (Kemp et al. 1997). All sites receive organic inputs from surrounding uplands, marshes, or mangrove forests. As bacteria break down that organic material, oxygen is consumed by bacterial respiration and nutrients are released or regenerated. Although those nutrients are then used to support primary production that produces oxygen, there are lags between input of organic matter, nutrient regeneration and subsequent production. However, when inorganic nutrients directly enter the system from upstream or land runoff, there is no lag in their use by phytoplankton.

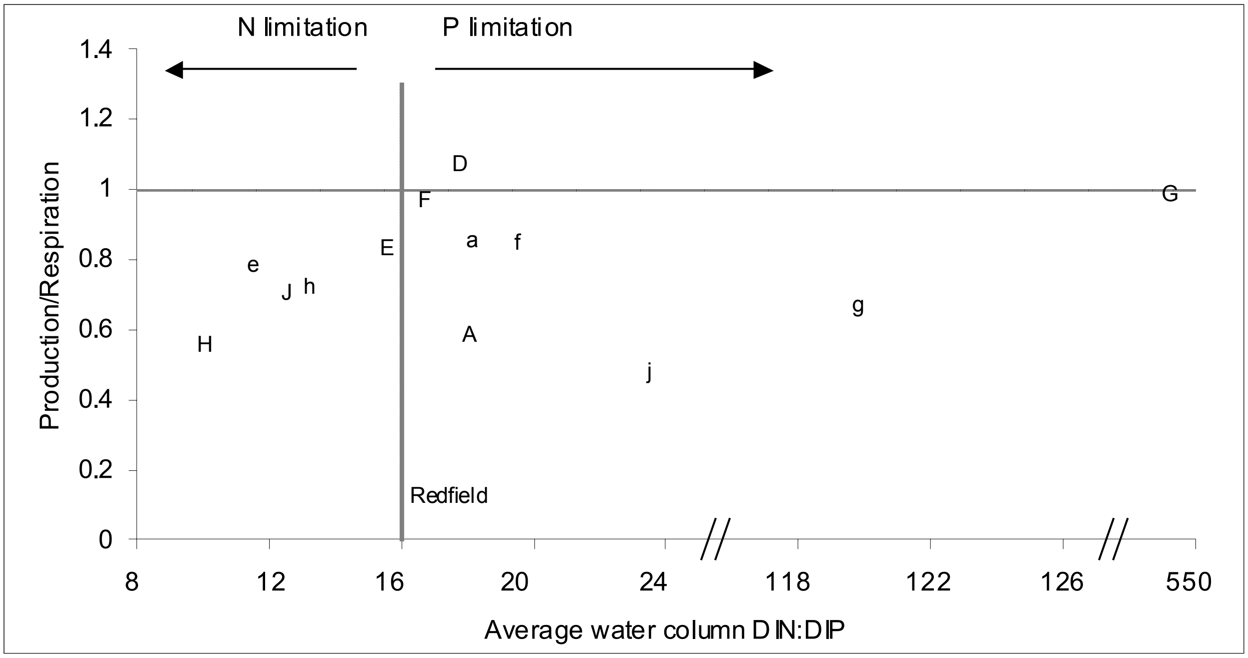

Figure 237. Ratios of dissolved inorganic nitrogen (DIN) to phosphate (DIP) vs. production to respiration.

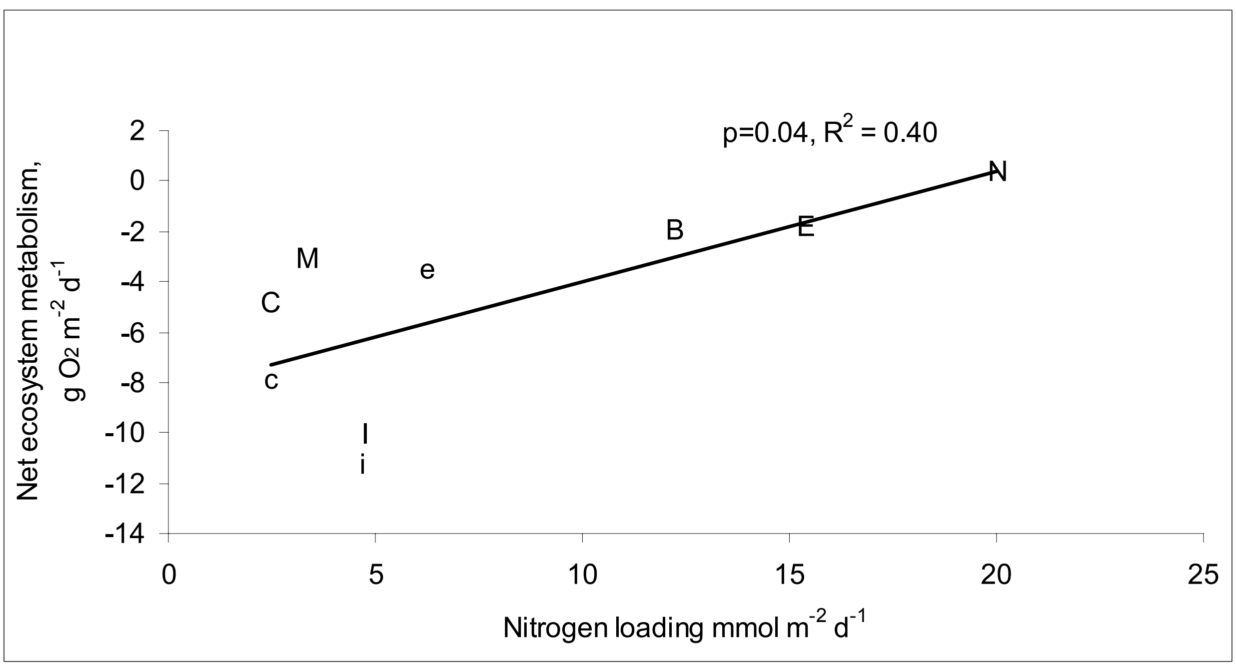

Figure 238. Net ecosystem metabolism versus nitrogen loading among selected NERR sites.